

## DRAWINGS ATTACHED

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## (54) DIFFERENTIAL SPECTRAL ABSORPTION ANALYSER

- (71) We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of STC House, 190 Strand, London, W.C.2, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—
- This invention relates to differential spectral absorption analysers, and in particular to means for providing such instruments with a form of automatic gain control. These instruments find particular but not exclusive application in the measurement of the concentration of a specific vapour by comparing in the infra-red region of the spectrum the absorption coefficient presented by the vapour at a wavelength at which it is known to be highly absorbing with the absorption presented by it at a nearby wavelength at which it is known to be relatively transparent.
- It is to be understood that in this specification the terms 'light', 'optical', and any other words related to optics such as 'light source' and 'photodetector' are not used in their narrow sense appertaining exclusively to the visible region of the electromagnetic spectrum, but are used in their wider sense appertaining also to the infra-red region of the spectrum.
- According to the invention there is provided a differential spectral absorption analyser for comparing the relative spectral absorption coefficients over two selected spectral ranges of a specimen present in the optical path of the analyser from a light source to a photodetector which analyser also includes in the optical path light modulating means adapted not only to modulate at a signal frequency the spectral content of light transmitted there-through but also to modulate at a pilot tone frequency at least twice as great as the signal frequency the intensity of light transmitted therethrough, wherein the output of the photodetector is connected via a variable gain amplifier to both first and second demodulators adapted to operate at the signal and pilot tone frequencies respectively, the output of the second demodulator being connected to the gain control input of the variable gain amplifier thereby providing the analyser with an automatic gain control loop, while the output of the first demodulator provides the output of the analyser.
- There follows a description of a differential spectral absorption analyser embodying the invention in a preferred form. The description refers to the accompanying drawings in which:—
- Figure 1 is a block diagram of the instrument;
- Figure 2 depicts the form of a two colour chopper disc employed in the instrument; and
- Figures 3(a) and 3(b) are circuit diagrams of the electronic parts of the block diagram of Figure 1;
- Figure 3(b) being a continuation of Figure 3(a).
- Referring to Figure 1, light from a source S is modulated by a chopper F before being received by a photodetector 1. The chopper F, which will be described later in further detail with reference to Figure 2, is designed to modulate the light at two different frequencies  $f_1$  and  $f_2$ . The modulation at the lower of these two frequencies,  $f_1$ , is a modulation of the spectral content of the light whereas the modulation at the upper frequency,  $f_2$ , which is about  $2\frac{1}{2}$  times the lower frequency, is an intensity modulation of the light. The spectral content modulation will produce an amplitude modulation in the output of the photodetector if the optical path between the source and the photodetector passes through spectrally selective absorbing material. Other factors may also contribute to this signal such as wave-length dependence in the emittance of the lamp and in the sensitivity of the photodetector. Therefore the output of the photo-

detector will in general contain components at frequencies  $f_1$  and  $f_2$ . Both these components are amplified by a variable gain amplifier 2, and then the amplified component at the frequency  $f_2$  is separated from that at the frequency  $f_1$  by a high pass filter 4 before being applied to automatic gain control circuitry 5 which demodulates the component at the frequency  $f_2$  to provide a signal to control the gain of the variable gain amplifier 2. Meanwhile the amplified component at the frequency  $f_1$  is fed to an amplifier 3 which incorporates a filter 6, for removing the component at the frequency  $f_2$ , and from thence to a synchronous detector 7 which demodulates the component at the frequency  $f_1$  to provide a signal for feeding to an output display 8.

Thus the light intensity modulation produced by the chopper F at the frequency  $f_2$  is seen to provide a pilot tone which is suitably removed in frequency from the signal at the frequency  $f_1$  to enable its easy extraction from that frequency and its utilisation in the automatic gain control circuitry 5 in such a way as to keep constant the mean level of the output of the photodetector. In this way the instrument is automatically compensated for instabilities and drift in the output of the source, the sensitivity of the photodetector, the gain of the amplifier 2, and in any extraneous absorption introduced into the optical path by dirt dust or the like, provided that such instabilities or drift are not spectrally selective over the range of the spectrum involved in the modulation at the frequency  $f_1$ .

The construction of the chopper F will now be described in greater detail with reference to Figure 2. It consists essentially of a transparent disc rotated about its axis at a stabilized rate by a motor (not shown). This disc supports a filter in the form of a ring which transmits light over a narrow wavelength band of infra-red. This filter contains regions 9 at which the passband of the filter is shifted in wavelength from that of the surrounding regions of the filter. These regions 9 all subtend the same angle at the centre of the disc and are disposed such that the intervening regions between adjacent regions 9 shall also all subtend the same angle at the centre of the disc, this angle being equal to that subtended by the regions 9 themselves.

The photodetector and source are positioned so that rotation of the disc will cause the detector to be alternately illuminated by light which has been transmitted through one of the regions 9 of the filter and by light which has been transmitted through one of the intervening regions. In this way it is seen that rotation of the disc will produce a spectral content modulation of the received light at a frequency dependent upon the number of regions 9 and the speed of rotation. In order to detect the presence and concentration of a specific substance in the optical path between the source

and the photodetector the passband of the region 9 is chosen to match a known absorption band of the substance while that of the intervening regions is chosen to have a similarly shaped pass band having approximately the same spectral width and peak spectral transmission lying at a nearby part of the spectrum at which the substance is relatively transparent. Alternatively the role of the regions 9 and that of the intervening regions may be interchanged.

On the opposite side of the disc from the filter there is formed either by etching or by photoresistive working a set of radially disposed substantially opaque lines 10. These traverse the regions 9 and the intervening regions and they are between two and three times as numerous as the regions 9 so that when the disc is rotated they will superimpose upon the spectral content modulation at a frequency  $f_1$  a light intensity modulation at a greater frequency  $f_2$  where frequencies  $f_1$  and  $f_2$  are sufficiently far removed from one another for electrical signals at these frequencies to be readily capable of separation by filtering.

Circuits diagrams for the above elements 1 to 8 are given in Figs. 3(a) and 3(b). The detector stage 1, includes a photo-responsive element (of any suitable type for the wavelength employed) which provides an electrical potential dependent on the incident illumination. This potential is applied to the base of T1 which provides a high input impedance to the amplifier (stage 2) formed by transistors T2 and T3 which are connected in cascade. The cut-off point of T2 is controlled by the base potential of T4. The output from the collector of T3 passes through a five-pole high-pass filter (stage 3) which cuts out the very low frequency components due to spurious effects such as turbulence, but whose cut-off frequency is low enough not to affect the signal frequency  $f_1$  at something above 600 c/s. The signal and the pilot tone frequencies are thus both present on the line at X, Figs. 3(a) and 3(b). The output at the collector of T6 in the high pass filter stage 3 is fed also to the high pass filter stage 4 which filters out the component at the signal frequency  $f_1$  but passes the pilot tone which is then fed to the base of T5 for current gain and rectification. The rectified pilot tone serves as an automatic gain control signal when applied to the base of T4, and compensates for the overall attenuation due to the optical path etc. as measured by the decrease in amplitude of the high frequency pilot tone component.

The high pass filter of stage 4 is again a five-pole Butterworth filter, however a band-pass filter or a suitable tuned circuit can be used as an alternative.

The signal frequency  $f_1$  together with the pilot tone at X pass in Fig. 3(b) to an amplifier and tuned circuit stage 6 which is tuned to the frequency  $f_1$  and thus rejects noise and

components at other frequencies including that of the pilot tone. The output of stage 6 which thus consists purely of spectral information is then applied to the base of transistor T7 in the synchronous detector stage 7.

5 Winding 12 at the collector of T7 is coupled to a centre tapped coil 13 which allows an indication of polarity reversal in the signal to be obtained. A sinusoidal waveform which is in phase with the signal in the windings, since it is derived from the original chopper filter disc through mechanical coupling, is applied between points 14 and 14, and is picked up by the centre-tapped winding 15 to control the ON/OFF times of transistors T8 and T9 thus permitting synchronous extraction of the spectral information.

10 In display stage 8, the spectral information is displayed as a reading on the meter 16, the germanium device T10 preventing too great an overload on the meter, and the presence of capacitor C giving a time constant during which a reading may build up. The meter may include means for indicating failure of the light source.

#### WHAT WE CLAIM IS:—

1. A differential spectral absorption analyser for comparing the relative spectral absorption coefficients over two selected spectral ranges of a specimen present in the optical path of the analyser from a light source to a photo-detector which analyser also includes in the optical path light modulating means adapted not only to modulate at a signal frequency the spectral content of light transmitted there-through but also to modulate at a pilot tone frequency a least twice as great as the signal frequency the intensity of light transmitted therethrough, wherein the output of the photo-detector is connected via a variable gain amplifier to both first and second demodulators adapted to operate at the signal and pilot tone

frequencies respectively, the output of the second demodulator being connected to the gain control input of the variable gain amplifier thereby providing the analyser with an automatic gain control loop, while the output of the first demodulator provides the output of the analyser.

2. An analyser means as claimed in claim 1 wherein the light modulating means includes a ring of filter elements the ring being divided into an even number of equiangular sectors alternate ones of which are occupied by a first set of identical filter elements whose spectral range is different from that of a second set of identical filter elements which occupy the intervening sectors.

3. An analyser as claimed in claim 2 wherein the ring of filter elements is supported on a transparent disc on which is formed a set of equiangularly spaced and radially disposed substantially opaque markings at least twice as numerous as the members of either set of identical filter elements.

4. An analyser as claimed in claim 1, 2 or 3 wherein the first demodulator is a synchronous detector.

5. An analyser as claimed in claim 3 or 4 wherein the light modulating means is substantially as hereinbefore described with reference to Figure 2 of the accompanying drawings.

6. A differential spectral absorption analyser substantially as hereinbefore described with reference to the accompanying drawings.

7. A vapour detector incorporating an analyser as claimed in any preceding claim wherein the two selected spectral ranges lie in the infra-red region of the spectrum.

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